

**Cs/Sr Waste Volume Estimates**

In Table 4.8.1, only three cases will generate Cs/Sr wastes:

Thermal Recycle Option 1

Thermal/Fast Recycle Alternative - Fast Reactor Recycle Only

Thermal/Fast Recycle Alternative - Thermal & Fast Recycle Option

For all three of these three cases, the amount of Cs/Sr waste is listed in Table 4.8.1 as 12 MT/yr.

The Integrated Waste Management Strategy (IWMS) gives a range for the volume of the waste forms from aqueous processing of spent PWR fuel as  $4 \times 10^{-3} \text{ m}^3$  to  $2.7 \times 10^{-2} \text{ m}^3$  per MTIHM of spent PWR fuel, which contains 7.99 kg of Cs/Sr and this includes Ba and Rb, since they are apparently separated along with the Cs and Sr from the UREX raffinate stream, according to the IWMS p. 9 and as listed in Table 2. This translates into a range of  $5 \times 10^{-4} \text{ m}^3$  to  $3.4 \times 10^{-3} \text{ m}^3$  per kg of Cs/Sr/Ba/Rb waste.

At the 20 year cooling time of the calculation, there is 3.3 kg Cs, 1.0 kg Sr, 3.07 kg Ba, and 0.53 kg Rb, for a total of 7.83 kg. (I don't know why there is a small difference here, about 2%, but there's probably a small amount of something else that comes along in the waste stream that isn't identified in the document, at least not that I saw in the quick read in the trying to answer this question.)

Processing time in the references used for the PEIS have the LWR spent fuel cooled for 5 years before processing. The fast reactor fuel is also processed at 5 years after discharge.

**Thermal Recycle Option 1:**

At 5 years after discharge,

2.128 kg Ba

3.593 kg Cs

0.374 kg Rb

0.866 kg Sr

Total: 6.961 kg per MTIHM of spent (U/Pu MOX Continuous Recycle) fuel at 45 GWd/MTIHM burnup. If there was another 2% of other elements, that would make about 7.1 kg per MTIHM. Since we process 2460 MTIHM/yr for 100 GWe-yr/year, this would be 17.467 MT/yr. At this time, 4.459 kg is Cs and Sr, which for 2460 MT/yr would be 10.969 MT/yr, about 11 MT/yr, not the 12 MT/yr listed in Table 4.8.1.

Note that at discharge,

3.898 kg Cs

0.928 kg Sr

Total: 4.826 kg per MTIHM spent fuel. For 2460 MTIHM/yr, this would be 11.872 MT/yr, which is consistent with the 12 MT/yr in Table 4.8.1. The 12 MT/yr would also represent the total of Cs/Sr/Ba/Y, since Ba and Y are decay products. We have to be careful about what the 12 MT/yr represents.

Since the UREX separation produces a waste stream which has Cs/Sr/Ba/Rb, if we use that mass of waste to get the volume, one would have the following for 100 GWe-y/year:

$$(17.467 \text{ MT/yr}) \times (1000 \text{ kg/MT}) \times (5 \times 10^{-4} \text{ m}^3/\text{kg of waste}) = 8.73 \text{ m}^3/\text{yr}$$

$$(17.467 \text{ MT/yr}) \times (1000 \text{ kg/MT}) \times (3.4 \times 10^{-3} \text{ m}^3/\text{kg of waste}) = 59.34 \text{ m}^3/\text{yr}$$

This is the range for the lower bound waste volume estimate.

From the NEPA data studies by SRS, they report 75184.8 kg per year for Cs/Sr waste stream for an 800 MT/yr CFTC facility using 60 GWd/MTIHM burnup spent fuel, so for 2460 MT/yr of 45 GWd/MTIHM burnup spent fuel, this would be:

$$(2460/800) \times (45/60) \times (75184.8 \text{ kg/yr})/1000 \text{ kg/MT} = 173.4 \text{ MT/yr.}$$

In terms of volume, this would be 4,075 canisters for the 800 MT/year facility with 60 GWd/MTIHM burnup spent fuel, so for 45 GWd/MTIHM burnup spent fuel there would be 3056 canisters with the canister volume being 0.019 m<sup>3</sup> each, for a volume of 58.1 m<sup>3</sup>. So for 2460 MT/yr, there would be (2460/800) x 58.1 = 178.6 m<sup>3</sup> as an upper bound for a waste volume.

### **For Thermal/Fast Recycle Alternative - Fast Reactor Recycle Only**

Aqueous processing is assumed for both the spent PWR fuel and the spent fast reactor fuel. For this alternative, 1350 MTIHM/yr of spent PWR fuel with 51 GWd/MTIHM burnup is processed and 335 MTIHM/yr of spent fast reactor fuel with 107 GWd/MTIHM burnup is processed for 100 GWe-yr/year.

For the spent PWR fuel at 5 years after discharge,

2.265 kg Ba  
3.950 kg Cs  
0.525 kg Rb  
1.227 kg Sr

Total: 7.968 kg per MTIHM spent PWR fuel. With another 2% for other elements, this is 8.13 kg per MTIHM. For UREX processing of 1350 MTIHM/yr of spent PWR fuel, this results in 10.98 MT/yr for the Cs/Sr waste stream with UREX processing.

For the spent fast reactor fuel at 5 years after discharge,

4.466 kg Ba  
11.44 kg Cs  
0.558 kg Rb  
1.199 kg Sr

Total: 17.66 kg per MTIHM spent fast reactor fuel. This is 2.2 times the inventory of these fission products in the spent PWR fuel, while the burnup is 2.1 times higher, indicating that the inventory of these fission products scales approximately with burnup. The value of 17.66 should probably be increased by about 2% to account for the other elements, for a total estimate of 18 kg/MTIHM. For 335 MTIHM/yr of spent fast reactor fuel being processed, this results in 6.03 MT/yr of Cs/Sr waste stream for 100 GWe-yr/year.

The total for this alternative is then 10.98 + 6.03 = 17.01 MT/yr for the Cs/Sr waste stream. This is about the same as for Thermal Recycle Option 1, which I would expect.

Since the UREX separation produces a waste stream which has Cs/Sr/Ba/Rb, if we use that mass of waste to get the volume, one would have the following for 100 GWe-y/year:

$$(17.01 \text{ MT/yr}) \times (1000 \text{ kg/MT}) \times (5 \times 10^{-4} \text{ m}^3/\text{kg of waste}) = 8.51 \text{ m}^3/\text{yr}$$

$$(17.01 \text{ MT/yr}) \times (1000 \text{ kg/MT}) \times (3.4 \times 10^{-3} \text{ m}^3/\text{kg of waste}) = 57.83 \text{ m}^3/\text{yr}$$

This is the range for the lower bound waste estimate.

From the NEPA data studies by SRS, they report 75184.8 kg per year for Cs/Sr waste stream for an 800 MT/yr CFTC facility using 60 GWd/MTIHM burnup spent fuel, so for 1350 MT/yr of 51 GWd/MTIHM burnup spent fuel, this would be:

$(1350/800) \times (51/60) \times (75184.8 \text{ kg})/1000 \text{ kg/MT} = 107.8 \text{ MT/yr}$ . In terms of volume, this would be 4,075 canisters for the 800 MT/year facility with 60 GWd/MTIHM burnup spent fuel, so for 51 GWd/MTIHM burnup spent fuel there would be 3464 canisters, with the canister volume being  $0.019 \text{ m}^3$  each, for a volume of  $65.8 \text{ m}^3$ . So for 1350 MT/yr, there would be  $(1350/800) \times 65.8 = 111.0 \text{ m}^3$  as an upper bound for a waste volume from processing spent PWR fuel.

(Sanity check: Note that 75184.8 kg of Cs/Sr waste stream for 800 MT/yr is 93.98 kg per MT of spent fuel processed. With a burnup of 60 GWd/MTIHM for the spent fuel, this becomes 1.566 kg of Cs/Sr waste stream per GWd generation. The Cs/Sr/Ba/Rb amount is 7.968 kg/MTIHM, or 0.156 kg/GWd. The rest is other materials, especially waste form matrix and process materials. This is about right given the data from SRS.)

From the NEPA data studies by SRS, they report 24768 kg per year for Cs/Sr waste stream for a 100 MT/yr fast reactor processing facility using 250 GWd/MTIHM burnup spent fuel (but with only 1 year cooling), so for 335 MT/yr of 107 GWd/MTIHM burnup spent fuel, this would be:

$(335/100) \times (107/250) \times (24768 \text{ kg})/1000 \text{ kg/MT} = 35.5 \text{ MT/yr}$ . (Since the waste stream includes Ba and Rb along with the Cs and Sr, while the Cs and Sr decay into Ba and Y, the difference in cooling time from 1 year to 5 years does not make a large difference in the total waste stream mass for the Cs/Sr waste stream.) In terms of volume, this would be 1,343 canisters for the 100 MT/year facility with 250 GWd/MTIHM burnup spent fuel, so for 107 GWd/MTIHM burnup spent fuel there would be 575 canisters with the canister volume being  $0.019 \text{ m}^3$  each, for a volume of  $10.9 \text{ m}^3$ . So for 335 MT/yr, there would be  $(335/100) \times 10.9 \text{ m}^3 = 36.5 \text{ m}^3$  as an upper bound for a waste volume from processing spent fast reactor fuel.

(Another sanity check: For this facility, 24768 kg of Cs/Sr waste stream for 100 MT/yr is 247.68 kg per MT of spent fuel processed. With a burnup of 250 GWd/MTIHM for the spent fuel, this becomes 0.99 kg of Cs/Sr waste stream per GWd generation. I would have expected this to be about the same as for the spent PWR fuel. The Cs/Sr/Ba/Rb amount is 17.66 kg/MTIHM, or 0.165 kg/GWd, which is about the same as for the spent PWR fuel. I'm not sure if the lower kg per GWd is cause for concern or not at this time, but it makes processing of spent fast reactor fuel look better. There may be a reason that processing higher burnup fuel is more efficient, perhaps.)

Total upper bound waste volume would be  $111.0 + 36.5 = 147.5 \text{ m}^3$ . Note that this is lower than for Thermal Recycle Option 1 due to the apparently more favorable waste generation for processing spent fast reactor fuel.

**Thermal/Fast Recycle Alternative - Thermal & Fast Recycle Option**

Aqueous processing is assumed for the spent PWR fuel, the spent PWR MOX, and the spent fast reactor fuel. For this alternative, 1400 MTIHM/yr of spent PWR fuel with 51 GWd/MTIHM burnup is processed, 165 MTIHM/yr of spent PWR MOX with 50 GWd/MTIHM burnup is processed, and 250 MTIHM/yr of spent fast reactor fuel with 105 GWd/MTIHM burnup is processed for the total of 100 GWe-yr/year.

For the spent PWR fuel at 5 years after discharge,

2.265 kg Ba

3.950 kg Cs

0.525 kg Rb

1.227 kg Sr

Total: 7.968 kg per MTIHM spent PWR fuel. With another 2% for other elements, this is 8.13 kg per MTIHM. For UREX processing of 1400 MTIHM/yr of spent PWR fuel, this results in 11.38 MT/yr for the Cs/Sr waste stream with UREX processing.

For the spent PWR MOX fuel at 5 years after discharge,

2.399 kg Ba

4.166 kg Cs

0.287 kg Rb

0.635 kg Sr

Total: 7.487 kg per MTIHM spent PWR MOX fuel. With another 2% for other elements, this is 7.64 kg per MTIHM. For UREX processing of 165 MTIHM/yr of spent PWR fuel, this results in 1.26 MT/yr for the Cs/Sr waste stream with UREX processing.

For the spent fast reactor fuel at 5 years after discharge,

3.990 kg Ba

10.26 kg Cs

0.500 kg Rb

1.073 kg Sr

Total: 15.82 kg per MTIHM spent fast reactor fuel. The value of 15.82 should probably be increased by about 2% to account for the other elements, for a total estimate of 16.14 kg/MTIHM. For 250 MTIHM/yr of spent fast reactor fuel being processed, this results in 4.04 MT/yr of Cs/Sr waste stream for 100 GWe-yr/year.

The total for this alternative is then  $11.38 + 1.26 + 4.04 = 16.68 \text{ MT/yr}$  for the Cs/Sr waste stream. This is again about the same as for Thermal Recycle Option 1, which I would expect.

Since the UREX separation produces a waste stream which has Cs/Sr/Ba/Rb, if we use that mass of waste to get the volume, one would have the following for 100 GWe-y/year:  $(16.68 \text{ MT/yr}) \times (1000 \text{ kg/MT}) \times (5 \times 10^{-4} \text{ m}^3/\text{kg of waste}) = 8.34 \text{ m}^3/\text{yr}$

$$(16.68 \text{ MT/yr}) \times (1000 \text{ kg/MT}) \times (3.4 \times 10^{-3} \text{ m}^3/\text{kg of waste}) = 56.71 \text{ m}^3/\text{yr}$$

This is the range for the lower bound waste estimate.

From the NEPA data studies by SRS, they report 75184.8 kg per year for Cs/Sr waste stream for an 800 MT/yr CFTC facility using 60 GWd/MTIHM burnup spent fuel, so for 1400 MT/yr of 51 GWd/MTIHM burnup spent PWR fuel, this would be:

$(1400/800) \times (51/60) \times (75184.8 \text{ kg})/1000 \text{ kg/MT} = 111.8 \text{ MT/yr}$ . In terms of volume, this would be 4,075 canisters for the 800 MT/year facility with 60 GWd/MTIHM burnup spent fuel, so for 51 GWd/MTIHM burnup spent fuel there would be 3464 canisters, with the canister volume being  $0.019 \text{ m}^3$  each, for a volume of  $65.8 \text{ m}^3$ . So for 1400 MT/yr, there would be  $(1400/800) \times 65.8 = 115.2 \text{ m}^3$  as an upper bound for a waste volume from processing spent PWR fuel.

Similarly, for 165 MT/yr of 50 GWd/MTIHM burnup spent PWR MOX fuel, this would be:

$(165/800) \times (50/60) \times (75184.8 \text{ kg})/1000 \text{ kg/MT} = 12.9 \text{ MT/yr}$ . In terms of volume, this would be 4,075 canisters for the 800 MT/year facility with 60 GWd/MTIHM burnup spent fuel, so for 50 GWd/MTIHM burnup spent fuel there would be 3396 canisters, with the canister volume being  $0.019 \text{ m}^3$  each, for a volume of  $64.5 \text{ m}^3$ . So for 165 MT/yr, there would be  $(165/800) \times 64.5 = 13.3 \text{ m}^3$  as an upper bound for a waste volume from processing spent PWR MOX fuel.

From the NEPA data studies by SRS, they report 24768 kg per year for Cs/Sr waste stream for a 100 MT/yr fast reactor processing facility using 250 GWd/MTIHM burnup spent fuel (but with only 1 year cooling), so for 250 MT/yr of 105 GWd/MTIHM burnup spent fuel, this would be:

$(250/100) \times (105/250) \times (24768 \text{ kg})/1000 \text{ kg/MT} = 26.0 \text{ MT/yr}$ . (Since the waste stream includes Ba and Rb along with the Cs and Sr, while the Cs and Sr decay into Ba and Y, the difference in cooling time from 1 year to 5 years does not make a large difference in the total waste stream mass for the Cs/Sr waste stream.) In terms of volume, this would be 1,343 canisters for the 100 MT/year facility with 250 GWd/MTIHM burnup spent fuel, so for 105 GWd/MTIHM burnup spent fuel there would be 564 canisters with the canister volume being  $0.019 \text{ m}^3$  each, for a volume of  $10.7 \text{ m}^3$ . So for 250 MT/yr, there would be  $(250/100) \times 10.7 \text{ m}^3 = 26.8 \text{ m}^3$  as an upper bound for a waste volume from processing spent fast reactor fuel.

Total upper bound waste volume would be  $115.2 + 13.3 + 26.8 = 155.3 \text{ m}^3$ . Note that this is also lower than for Thermal Recycle Option 1 due to the apparently more favorable waste generation for processing spent fast reactor fuel with higher burnup, but a little higher than for the fast reactor only recycle option.